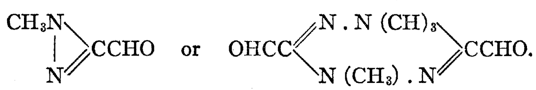
calcium chloride a crystalline precipitate soluble in hydrochloric acid and reprecipitated by ammonia.

The hydrochloric acid solution of the base, obtained by decomposing the water solution of the gold salt with hydrogen sulphide, gives with phenylhydrazine and potassium acetate at about 40° a reddish brown, partly crystalline, partly resinous solid, easily soluble in organic solvents (except ligroin), which, when dissolved in a little alcohol and poured into much boiling water, separates on cooling in fine felted needles melting at 159° when heated slowly and at 162–3° when the capillary is introduced into a bath previously heated to 150°.

With the data at his disposal Abel in 1903 suggested that the base might well be a highly unstable cyclic compound related to the pyrazolone series. In 1906 Curtius began publishing the results of his interesting investigations on the series of compounds obtained by the action of alkalies on diazoacetic ester,[2] and our new base in so many respects (namely, in its decomposition into methylhydrazine, methylamine, ammonia and oxalic acid) so closely resembles his 'pseudodiazoacetic acid' derivatives that it may not appear too hazardous to suggest that it contains the isodiazomethane or N-1,4-dihydro-1,2,4,5-tetrazine grouping and that its constitution may be represented by the formula



This suggestion is made with all reserve and it is hoped that certain experiments now being carried out will soon make it possible to decide whether or not it is tenable.

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[1] Abel, J. J., *Amer. J. Physiol. Proc.*, 8, 31 (1903); *Ber. D. chem. Ges.*, **36**, 1846 (1903); **37**, 368 (1904); Abel and Taveau, R. deM., *J. Biol. Chem*, **1**, 13 (1905).

[2] For a summary of the work of Curtius on these compounds, see *Ber. D. chem. Ges.*, **41**, 3161 (1908); also *Ibid.*, **42**, 3284 (1909).

EXTINGUISHED AND RESURGENT CORAL REEFS

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In the diagrams by which Darwin originally illustrated his theory of upgrowing reefs on subsiding foundations, the reefs were drawn as growing upward and inward, in such a way that the diameter of their

ring diminished, but he did not explain the cause of the diminution. Dana used similar diagrams and insufficiently explained the diminution of diameter by saying:—"a barrier, as subsidence goes on, gradually contracts its area, owing to the fact that the sea bears a great part of the material inward over the reef" (Corals and Coral Islands, 1872, 263). Certain later diagrams, especially one by Lendenfeld (Westermann's *Monatshefte*, 1896, 499–519), represents a reef as growing upwards and outwards, and hence of increasing diameter. Daly adopts essentially this view and adds:— "When one remembers that most of the detritus abraded from the main reef goes to form talus on the outer submarine slope; and, secondly, that the growth of new coral is much faster on that side, we cannot fail to expect a centrifugal tendency for the encircling reef, as the island sinks" (Glacial-Control Theory of Coral Reef, Proc. Amer. Acad., li, 1915, 247). Both increase and de-

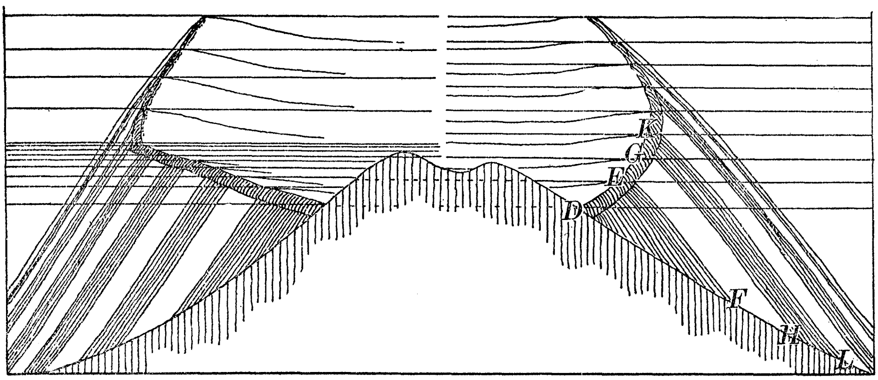

FIG. 1.

crease of reef diameter may take place, for both outward and inward upgrowths are possible, but in atolls that have grown upward during long continued subsidence in a deep ocean, diminution of diameter with inward growth is the more probable for the following reasons.

Let a sea-level fringing reef be formed around a young volcanic cone at *D*, figure 1, and let the horizontal lines on the right side of the figure represent successive levels of the sea with respect to a uniformly subsiding cone. Let the subsidence be so slow that the reef at first grows upward and outward, *DE*, on its own talus, which lengthens as subsidence progresses. The talus material consists chiefly of fragments broken by waves from the corals and other organisms which grow on the outer face of the reefs. In a given period of time, a growing reef face of given perimeter and 20 fathoms deep cannot produce more than a certain maximum volume of new growth; and as some of the

new growth stands firm to build the reef upward, while some is broken off and washed inward to form the flat reef and the lagoon shoals, only the remainder can be sacrificed for the talus. Let this remainder be represented in section by *DEF*. If equal remainders are applied to talus building in equal time intervals, they may be represented by the shaded and unshaded quadrilaterals, *EFHG*, *GHLK*, etc., in which the breadth diminishes as the length increases.

So long as the reef growth is inclined outward, its increase in perimeter will, by providing a larger volume of coral growth, aid in supplying the demand for more talus material due to increase of depth; it is indeed conceivable that, if a reef foundation subsides very slowly and of the talus slants down to a level ocean floor of moderate depth, increase of perimeter may more than compensate for increase of talus length in the deepening water. In this case, outgrowth will continue at a constant or a lessening instead of at a steepening angle, as on the left side of figure 1. Especially favorable conditions for outward growth are provided when two islands stand so near each other that the submerged saddle between them is of moderate depth; for then the talus slopes on the line connecting the two island centers will be of decreasing length, if the rise of the talus intersection is faster than the subsidence of the islands. In such a case, reef cusps would tend to grow toward each other, and on uniting, the two concave reef faces would diminish their concavity by growing outward faster than the convex reef faces elsewhere, because the talus beneath a concave reef face is concentrated and thickened on converging lines of slope, while beneath a convex reef face it is distributed and thinned on diverging lines of slope. The double-looped barrier reef that encloses Makongai and Wakaya in central Fiji appears to be an example of this kind: on the other hand, four oval atolls north of the Exploring Isles in eastern Fiji, separated from each other by less distance than that which separates Makongai and Wakaya, show little tendency to develop approaching cusps; hence subsidence there may have been relatively rapid; and this is made probable by the occurrence of several 'drowned atolls' not far to the northeast.

But when the reef talus is built on the slope of a volcanic cone that rises from a deep ocean, the increase of coral growth on an enlarging reef perimeter may not fully compensate for increase of talus material demanded, especially if subsidence be relatively rapid; then the reef growth must be steeper in the second subsidence interval, *EG*, than in the first, *DE;* steeper in the third than in the second, and so on, in order that the thinner talus increments shall support it: otherwise the

reef would have to grow outward in an overhanging, unsupported cornice. It is true that when upward growth becomes steep, the share of it that stands firm to build the reef upwards is smaller than before; thus the part that may be sacrificed for talus building is larger; but this will not make up for the increased demand due to increased talus length. A time must therefore come when upgrowth passes the vertical and thereafter inclines inward, as above *K:* then a decrease of perimeter sets in and the total volume of coral growth diminishes, while the demand for talus material still increases. Under these conditions, the angle of inward upgrowth must soon come to be but little steeper than the angle of talus slope. An atoll reef which has been reduced to a diameter of a mile when this condition is reached, will be reduced to a point when subsidence has progressed about 2000 feet farther. If subsidence then still continues the reef will be extinguished. Dana reached essentially the same conclusion, but without analysis; he briefly asserts that subsidence will gradually reduce the size of an atoll 'until it finally becomes so small that the lagoon is obliterated;' then, if "subsidence continues its progress . . . . it finally sinks the coral island, which, therefore, disappears from the ocean" (Corals and Coral Islands, 1872, 322, 323). Thus a difference may be drawn between atolls that are 'extinguished' by the reduction of their diameter to zero during a uniform subsidence (or during an intermittent subsidence at a constant average rate), and atolls that are 'drowned,' as Moresby phrased it, by a too rapid subsidence, whatever their diameter may be.

It is evident that many variable factors would enter the equation by which the ultimate extinction of a reef might be expressed; form of ocean floor, "rate of subsidence and length of intervening stationary periods" as Darwin phrased it, rate of coral growth, and strength of wave attack are the more important factors. The change in angle of upgrowth due to a change from slow to rapid subsidence is shown on the left side of figure 1. Further, an extinguished reef would be brought to light if subsidence were reversed into upheaval; such a reef might then increase in size if upheaval paused or halted; and thus increased, it might if subsidence were renewed again grow up for a while before being extinguished for a second time. Extinguished reefs thus brought to light may be called 'resurgent.'

Many smaller reefs in Fiji appear to be resurgent, as thus defined. A good example is Frost reef, *F*, figure 2, a third way between Mango, *M*, 7 miles to the east, and Vatu Vará, *V*, 13 miles on the west. Mango appears to be a denuded caldera ring 3 miles in diameter, which has been submerged 450 feet or more and rimmed at that level with a fringing

reef, then uplifted 450 feet, and again fringed at present sea level; its highest summits now rise 650 feet above the sea. Vatu Varâ is a former atoll, presumably formed during subsidence, but now standing 1030 feet above sea level and nearly 2 miles in diameter at its base; it is the highest elevated reef in Fiji. According to Andrews its steep slopes are contoured above and below mid-height by two corniced "water-lines;" hence its uplift must have been recent and rapid: like Mango, it is now fringed by a sea-level reef. Frost reef is a mile in diameter: it has no lagoon. Soundings of 103, 115, 134, 146, and 133 fathoms are charted at less than half a mile away; 200 fathoms and no bottom are recorded at three points toward Mango. If Frost reef be diminished by removing a fringe of somewhat less than the average sea-level fringe-width now surrounding Mango or Vatu Varâ, it will be reduced to a mere point; and as such it was probably extinguished while Mango and Vatu Varâ were subsiding; it must eventually have been submerged

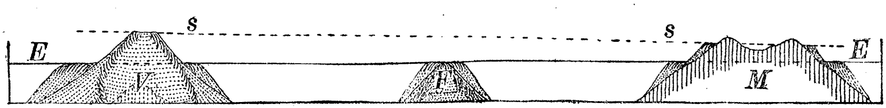

FIG. 2.

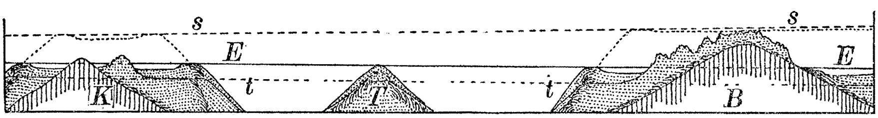

FIG. 3.

under more than 100 fathoms of water, when the highest reefs of Mango and Vatu Varâ were at sea level, *ss;* but it was revealed as a resurgent reef when the following uplift brought sea level to *EE*.

Midway in the eight-mile passage between the great barrier reef of the Exploring Isles, *B*, and Kimbombo reef, *K*, on the north is Trigger rock, *T*, figure 3, a minute reef in four fathoms of water, with the 100-fathom circle hardly half a mile in diameter, and soundings of 110, 121, 154 and 136 fathoms close outside. This rock must have been extinguished during the subsidence in which the now-elevated limestones of the Exploring Isles and Kimbombo were accumulating, and then submerged to a depth of 100 fathoms or more when the highest limestones were formed at the level *ss;* but a later upheaval brought it to light again as a resurgent reef, with sea level at *tt;* then it may have been recolonized for a time while the neighboring elevated limestones were suffering dissection; now, since the dissected limestones have again subsided, so that sea level is *EE*, the reef is almost extinguished

for a second time. It is interesting to note that the upheaval of the Exploring Isles, by which the previously extinguished Trigger reef became resurgent, was of a significantly earlier date than the resurgence of Frost reef between Mango and Vatu Varâ; for the limestones of these two islands are little dissected, while those of the Exploring Isles have been eroded to mere remnants of their former volume. It is the present almost-extinction of Trigger rock in a renewed subsidence of its region that is contemporaneous with the resurgence of Frost reef. Darwin's theory of intermittent subsidence is the only one of many coral-reef theories, which can account for the facts here adduced.

THE ORIGIN OF CERTAIN FIJI ATOLLS

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The unconformable contact of many fringing reefs on the eroded submarine slopes of oceanic islands, and the embayment of such islands inside of barrier reefs are inconsistent with certain modern theories of coral reefs; and the recognition of these significant features has in recent years led several observers back to Darwin's earlier theory of upgrowth on intermittently subsiding foundations. My own experience two years ago, while on a Shaler Memorial voyage across the Pacific concerning which a brief report has been published in these PROCEEDINGS (**1**, 1915, 146–152), added evidence of reef formation during two periods of subsidence; the first subsidence being shown by the occurrence of elevated reef limestones resting unconformably on eroded volcanic foundations, as seen in Vanua Mbalavu and Avea, two of the reef-encircled cluster of the nine Exploring Isles in the eastern part of the Fiji group, the second subsidence being shown by the embayment of these now-dissected limestones, around which a new barrier reef has grown up, as stated more fully in the *American Journal of Science* for September, 1915.

Continued attention to this problem has lately enabled me to perceive that the evidence of two periods of subsidence and reef growth found in the Exploring Isles may be extended to several neighboring atolls, the area concerned being well shown in Plate 19 of Agassiz' "Islands and Coral Reefs of Fiji" (*Bull. Mus. Comp. Zool.*, xxxiii, 1899): thus singularly enough a reconciliation is permitted between Agassiz' theory of the formation of atolls on uplifted and worn-down limestone islands and Darwin's theory of the formation of atolls by upgrowth on